Advanced Signal Timing Seminar

For: *Metropolitan Transportation Commission*
Technology Transfer Program

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Presentation Outline

I. Signal Preemption
II. Signal Priority
III. Signal Coordination Across Incompatible Systems
IV. Other Signal Timing Features
V. Signal Timing for Pedestrians and Bicyclists

I. Signal Preemption

- Goal:

  To transfer normal traffic signal operation to a special operation needed to accommodate immediate service of high priority vehicles

- Two Types:
  - Railroad Preemption
  - Emergency Vehicle Preemption

Railroad Preemption

- Typical:

  Simultaneous Preemption - Notification of an approaching train is sent to the traffic signal controller and railroad active warning devices at the same time.

- New Requirement:

  Advance Preemption - Notification of an approaching train is sent to the traffic signal controller in advance of the activation of the railroad active warning devices.

Example. UPRR At-Grade Crossing on 65th/Shellmound/Overland in Emeryville

Advance Preemption

- Requires the traffic controller to process two signals:
  - *Advance preemption* signal
  - *Railroad gate down* signal
- *Advance preemption* triggers the track clearance sequence at the traffic controller
- Track clearance sequence is held until *railroad gate down* is received
- When *railroad gate down* is received, the traffic controller releases track clearance and moves to limited or flashing operation
- Railroad exit sequence is initiated when both the *advance preemption* and *railroad gate down* are released

Advance Preemption

- Ensures that adequate track clearance is serviced before the gates are lowered
- Requires multiple preemption inputs under a single railroad preemption sequence not currently supported by existing traffic systems
- Special programming is necessary to:
  - Engage and hold the advance preemption sequence (track clearance)
  - Utilize the second preemption call to cancel the first preemption sequence (track clearance) and start flashing or limited operation

Emergency Vehicle Preemption

- Skips or truncates phases as necessary to serve EVP phase(s)
- Detection strategies
  - Optical (Opticom)

  - Directional Radio (Emtrac)

EVP Timing

- Return phase(s): first phases after service (typically next phases)
- Delay: time before call is placed to prevent false calls (2-4 seconds)
- Minimum duration: shortest period the call is active to prevent dropped calls (10-20 seconds)
- Maximum duration: longest period a call can be active
  - Could occur if emergency vehicle stops between intersections and maintains emitter/radio signal - infrequent
  - Not necessary when emitter/radio signal ends when emergency vehicle opens door or vehicle engine is off
  - Some agencies will not use this feature to prevent dropping of needed calls

EVP Timing

MUTCD (2003) Section 4D.13 Standard states "The shortening or omission of any pedestrian walk interval and/or pedestrian change interval shall be permitted".

- Walk time
  - Some controllers automatically terminate the walk while others allow a minimum time for each phase
- Flashing Don't Walk (Pedestrian Clearance)
  - Some controllers do not allow reduction of the FDW, while others allow the time to be reduced or terminated upon EVP call
  - Careful consideration should be made in reducing the FDW time

II. Transit Signal Priority (TSP)

- Goal
- Bus Priority
  - Priority Types
  - Detection Technologies
  - Priority Scenarios
  - Controller Settings
  - Implementation Considerations
- Light Rail Priority

Transit Signal Priority (TSP)

- Goal:
  - To provide preferential treatment to mass transit vehicles while minimizing impacts on vehicular traffic
- Unlike preemption, TSP does not allow reduction or termination of pedestrian clearance times
- Two Types:
  - Passive
  - Active
    - Headway-Based
    - Schedule-Based

Passive Priority

- Signal coordination to favor the progression of transit vehicles without the use of transit vehicle detection technologies or TSP interactions
- Dwell times at stops are estimated to develop the progression schemes
- Used mostly for one-way progression
- Impacts to vehicle progression primarily in the direction opposite the transit vehicle progression
- Not very reliable

Example. Broadway in Oakland

Passive Priority

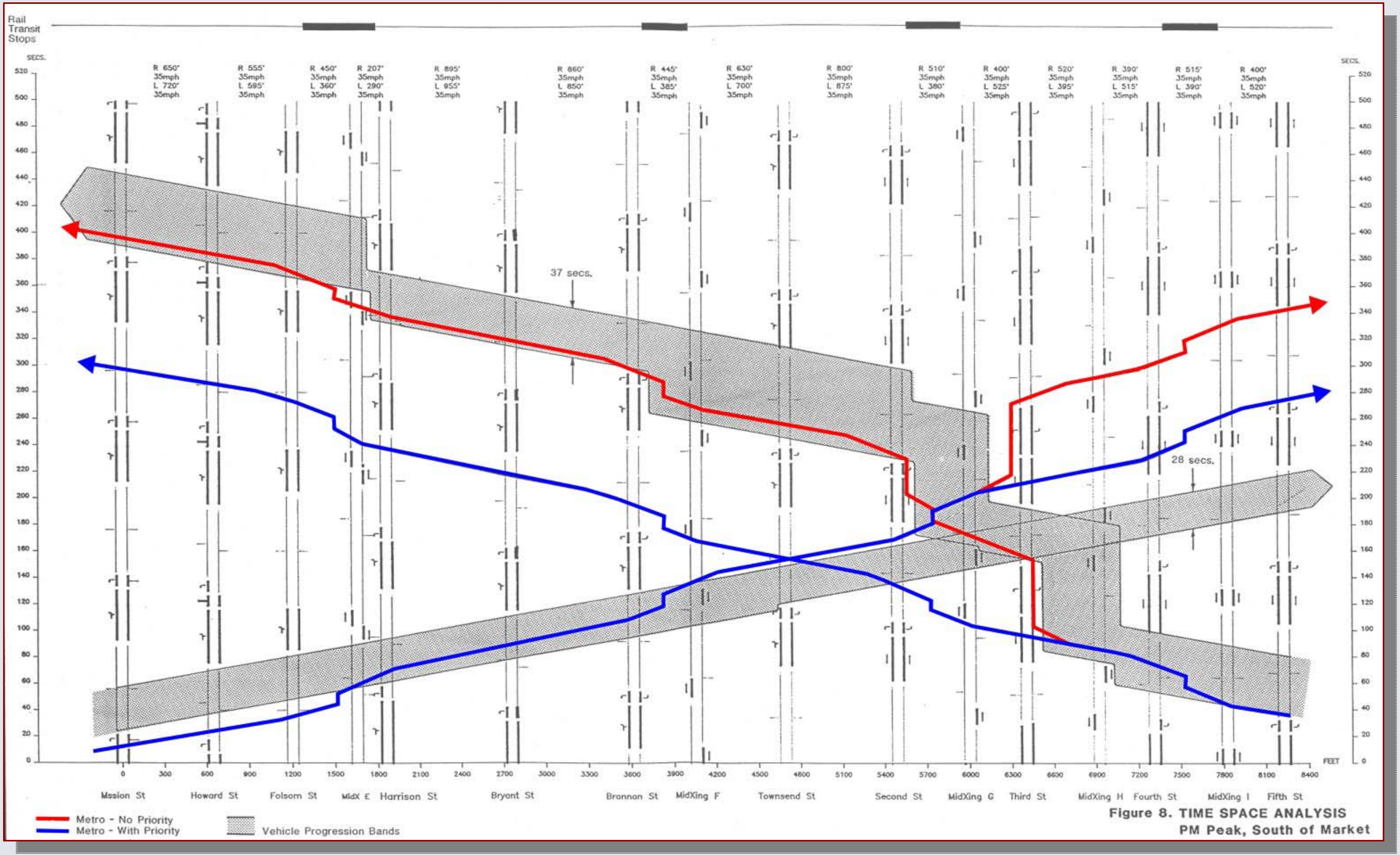


Figure 8. TIME SPACE ANALYSIS
PM Peak, South of Market

Active Priority

- Uses transit vehicle detection technologies and priority algorithms to service a transit vehicle
- Typically uses early green or green extension to service a priority call
- Two types:
  - Headway-Based
  - Schedule-Based

Headway-based TSP

- TSP requests granted based on pre-determined time interval, e.g., every 10 minutes
  - Some systems may not grant more than one call within the interval, so some calls may not be served
- TSP emitter is always on
- Simple and cost effective to implement

Example. *San Pablo Avenue*

Schedule-based TSP

- TSP is requested and granted only when a transit vehicle is behind schedule
- TSP emitter turned on only when needed
- Requires an AVL and scheduling system to determine whether bus is behind schedule

TSP Detection Technologies

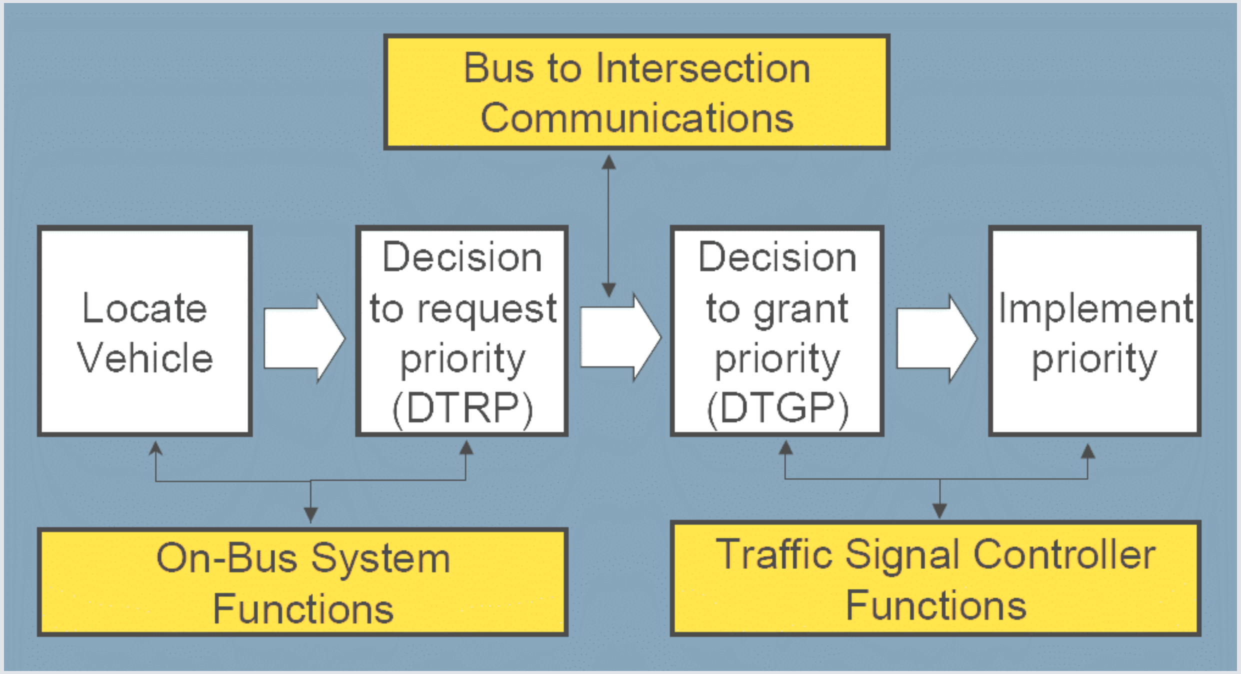
- Optical
- Radio
  - WLAN
  - Directional
- GPS/AVL
- Signal Interconnect for cascading calls

Optical Detection for TSP

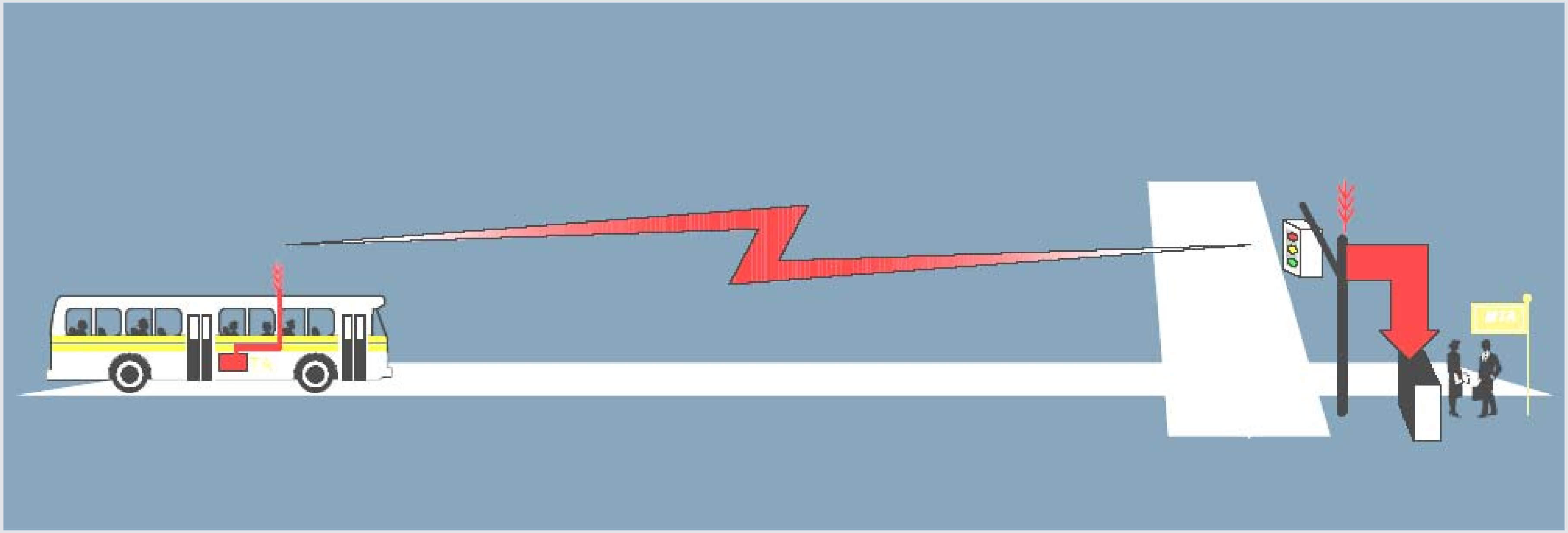
- Most common is 3M
- Optical emitter on board the transit vehicle
- Optical detector/receiver at the traffic signal
- Good range – up to 1500 feet with good line of sight
- Uses different light pulses to discriminate between a high (EVP) and low (TSP) priority call

WLAN Detection for TSP

- Uses directional radios on-board the bus to communicate with traffic controller
- On-board system determines whether the bus needs priority to get back on schedule

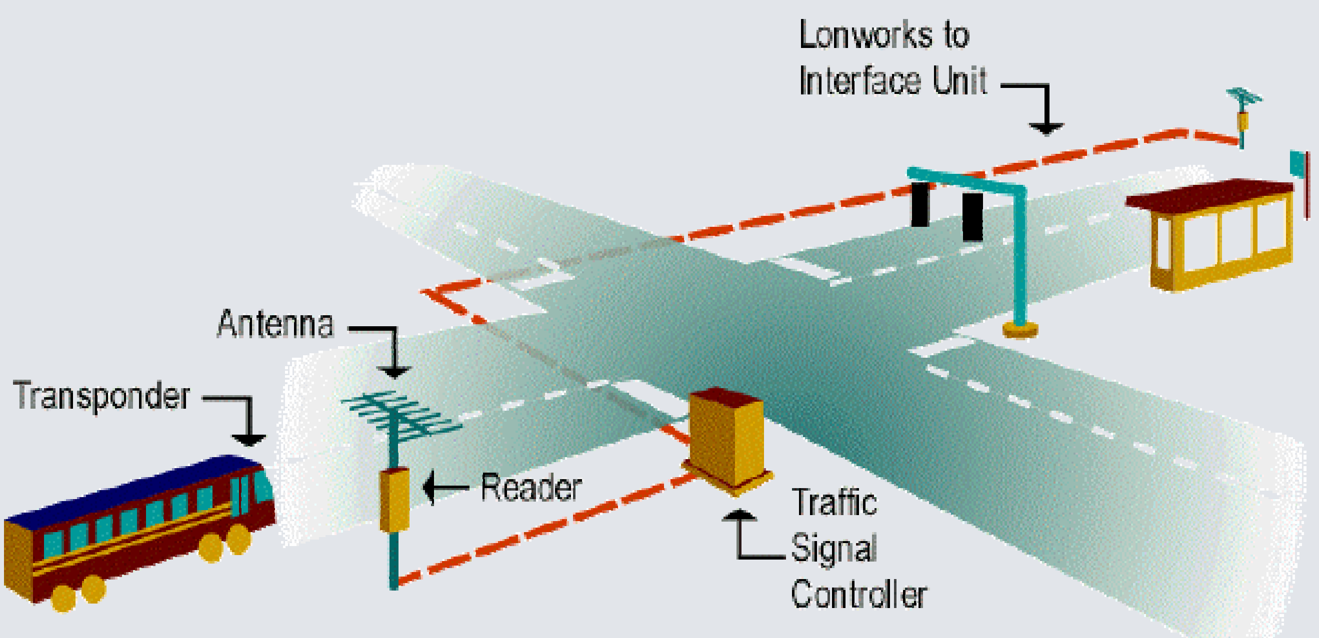


TSP using WLAN



Directional Radio for TSP

- On-board RF (radio frequency) tag
- Tag is activated by roadside antenna and tag reader unit

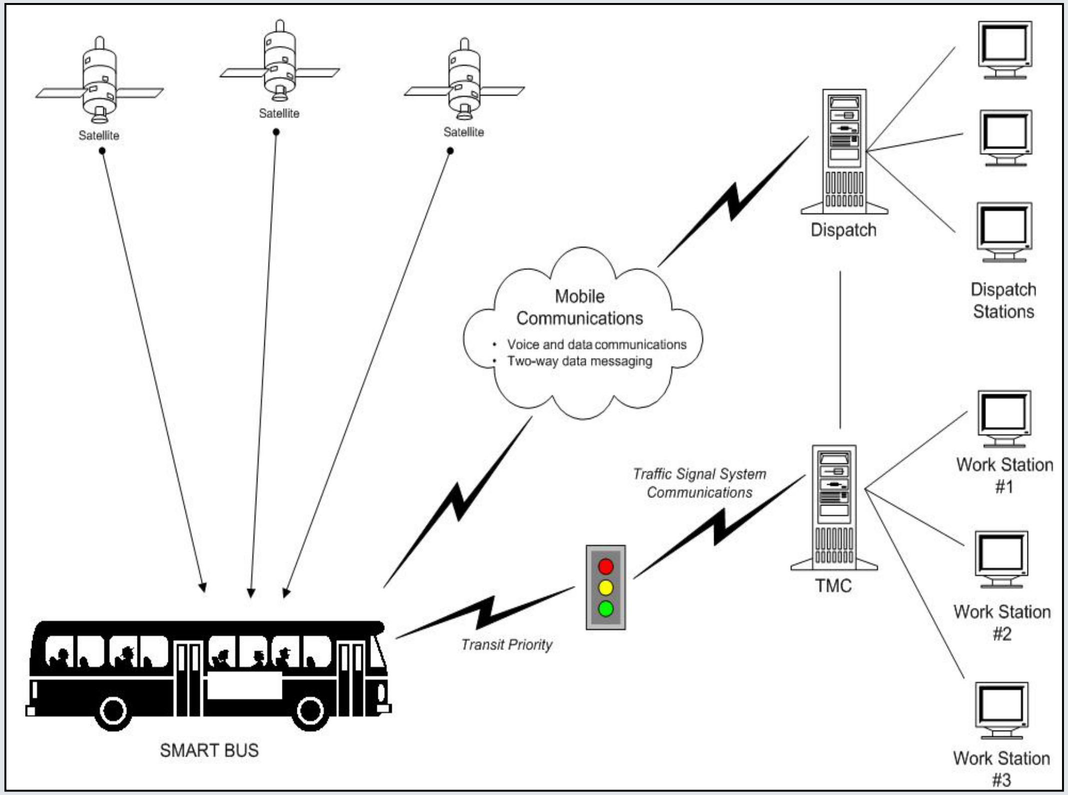


GPS/AVL for TSP

- Uses global positioning system (GPS) to track location of transit vehicles
- Uses automatic vehicle location (AVL) scheduling software to determine whether a bus is behind schedule
- If bus is behind schedule, the system commands a computer on the bus to turn on the TSP emitter

GPS/AVL for TSP

Process



Equipment

Interconnect for Cascading TSP Calls

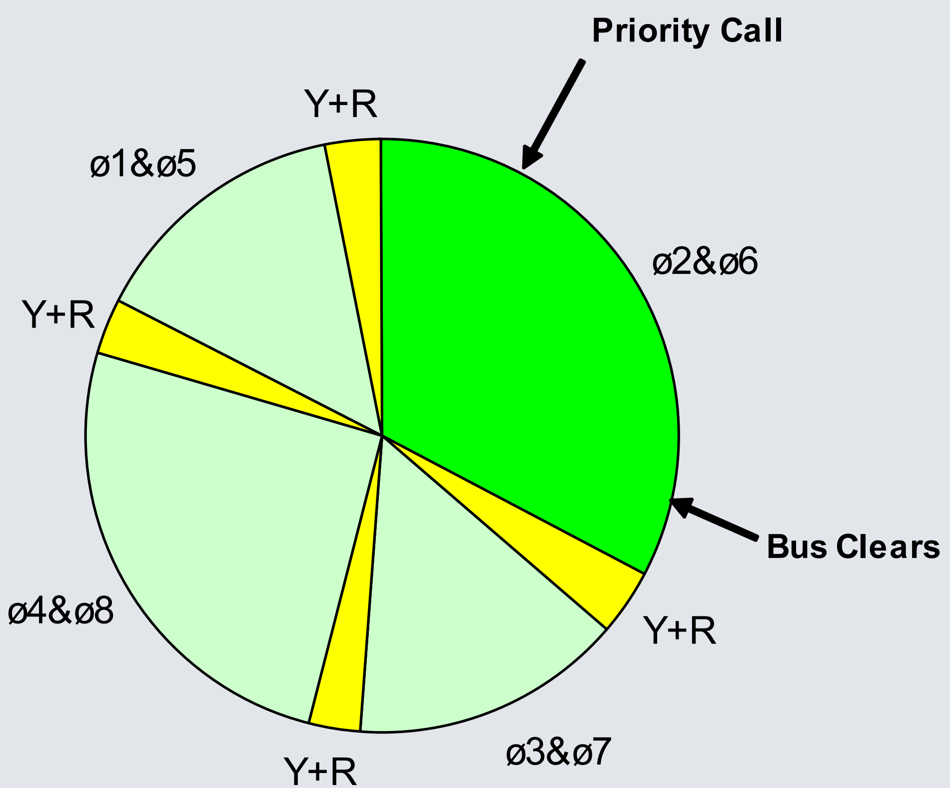
- Sends a TSP call to multiple traffic controllers using interconnect cable
- Most upstream traffic controller receives a TSP call, processes it, and forwards the TSP to the next downstream traffic controller
- Next downstream traffic controller does the same (process and send)
- Provides more time for the traffic controllers to react and service the transit phase

TSP Scenarios

- Do Nothing
- Extended Green
- Early Green
- Transition and Recovery

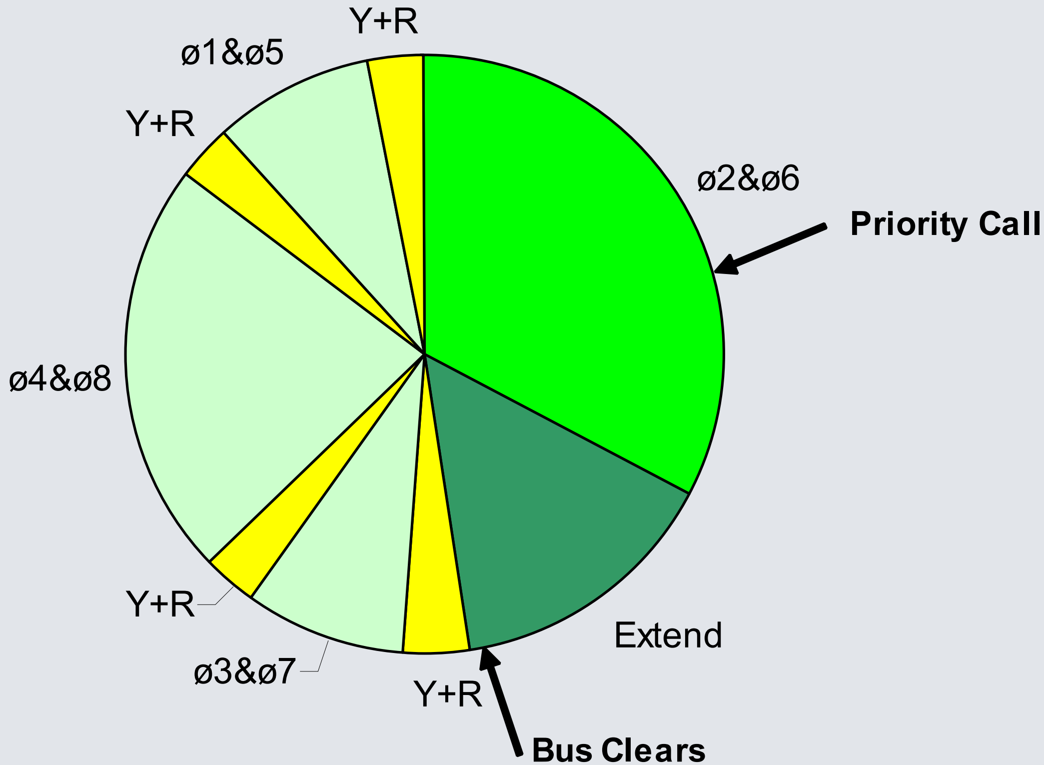
TSP Scenario – Do Nothing

- Priority call is placed prior to or during the priority phase, but can clear during the normal split time



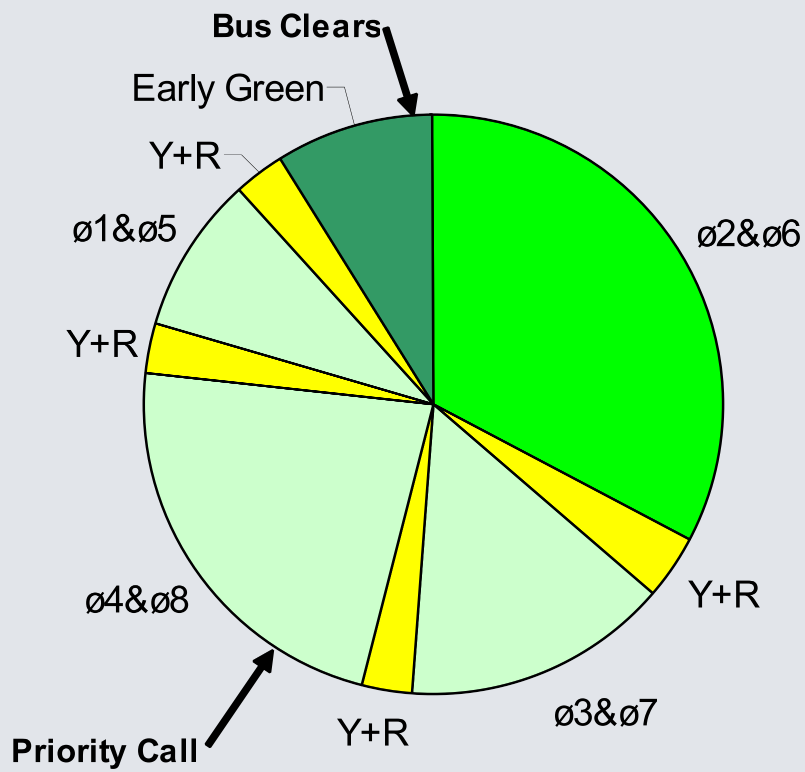
TSP Scenario – Extended Green

- Priority call is placed prior to or during the priority phase, but requires extended green to clear the intersection



TSP Scenario – Early Green

- Priority call is placed when priority phase is not active and therefore the priority phase receives an early green



Transition and Recovery from TSP

- Varies from one controller software to another
- Early green TSP needs no recovery
  - Controller is back in “sync” at the end of that coordinated green
- Extended green TSP can recover in one of two ways:
  - Shorten the following non-transit phase, or
  - Give the following non-transit phase the full split and shorten the next cycle’s transit phase

Controller Settings for TSP

- Can be used in either free or coordinated mode
- Maximum extension or minimum reduction
  - Designate minimum splits
  - Maximum reduction of splits as a % of cycle length
- Frequency of granting (time or cycles)
  - Weigh expected benefit vs. potential for increased delay

Controller Settings for TSP

- Call Delay time and/or Arrival time
  - Calculate based on where call is placed and bus travel time
- Phase omit (some controllers)
  - Consider for very minor movements only
- Time-out setting
  - Controlled by splits or set by travel time

TSP Implementation Considerations

- Cost
- Complicated operations analysis
  - VISSIM or other simulation software
    - Relatively high cost to develop, but fairly accurate especially if using virtual controller software on controller interface
  - Synchro
    - Lower cost to develop but less accurate
    - Can model “worst case” maximum early green or extended green and subsequent non-transit phases to determine recovery time
- Potential to increase ridership vs. potential to increase side street delay
- Compatibility of signal systems if implemented across different jurisdictions

Light Rail Transit Priority

Different Priority Types:

- Partial
  - Priority operations under coordination, no phase skipping, similar to bus TSP
- Full
  - Priority operations under free (uncoordinated) conditions, phase skipping allowed, similar to preemption
- Special
  - Priority operations under coordination, phase skipping allowed, little or no transition time

Parameters for LRT Priority

- LRV Travel Time – time for train to arrive at signal when a call is placed
- Phase truncation maximums – amount of time a signal or walk phase can be shortened
- Phase skipping parameters – designating which phases can be skipped
- Overlap assignments, e.g., offset intersections
- Special functions – EMS, gates

III. Coordination for Incompatible Systems

- Problem:
  - Different systems can have different times, so offsets may not be accurate
- Goal:
  - Establish effective traffic signal coordination for arterials with signals that belong to different systems
- Methods for Ensuring Same Time Reference
- Timing Considerations
- *Example.* Bascom Avenue Flush Plans

Methods for Ensuring Same Time Reference

- Similar systems that can communicate directly
  - Allows exchange of both time and control information
  - Sufficient for traffic responsive or traffic adaptive operation
- Similar systems that can communicate time information only
  - Example: Caltrans C8 with BI Tran Master software
  - Sufficient for time-based coordination

Methods for Ensuring Same Time Reference

- Dissimilar systems that can still communicate
  - Systems are interconnected and one system can receive a hardwire pulse from the other
  - Hardwire pulse tells other system to start coordination
- Dissimilar systems that do not communicate
  - Install GPS clocks or WWV clocks in each system or
  - Manually set clocks to same time
    - Amount of clock “drift” depends on controller type

Timing Considerations

- Signal timing preferences (ped/bike timing, cycle length preferences, lead/lag operation)

- References and parameters settings for each system, i.e. offset is beginning of green or beginning of yellow, etc.
- Cycle lengths needed to accommodate varying traffic patterns and signal characteristics between jurisdictions
    - Half-cycling for smaller signals or at interchanges
    - Signal groupings
    - Alternatives
    - Expected benefit

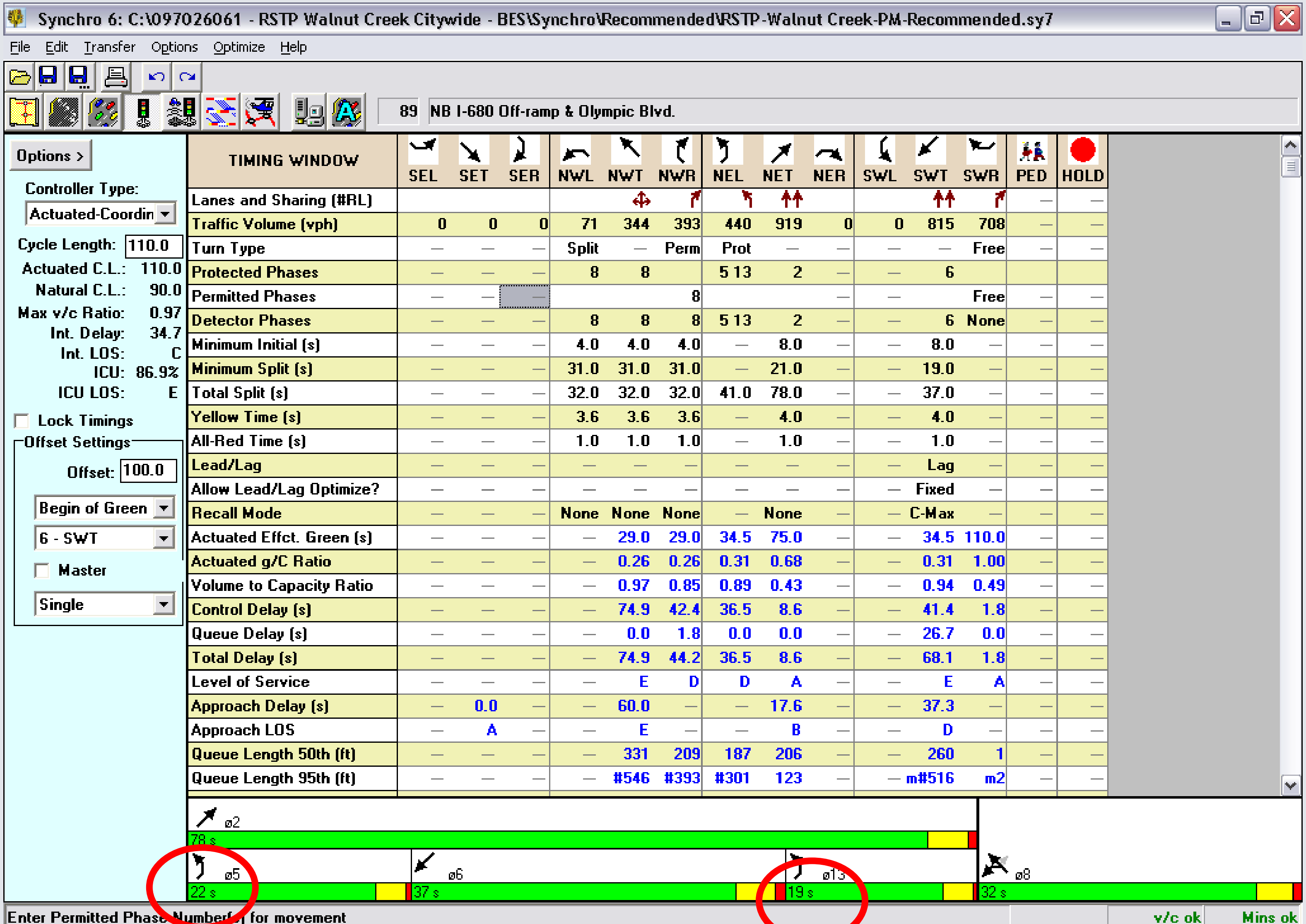
IV. Other Signal Timing Features

- Twice-per-Cycle Left Turns
- Variable Lane Control
- Single-Point Urban Interchanges
- Bus Queue Jumping
- Balancing Corridor Needs
- Ramp Metering Operations

Twice-per-Cycle Left Turns

- Left turn phase is served twice within a single cycle, first as leading then lagging
- Generally program lagging left as the standard phase designation + 8 (i.e. ø1 = ø9, ø5 = ø13)
- When to use:
  - Heavy left turn volume and short turn pocket
  - Minor intersections with sufficient time at the end of the coordinated phase to serve the left a second time
- Draw-backs:
  - Additional clearance time
  - May be unexpected by motorists

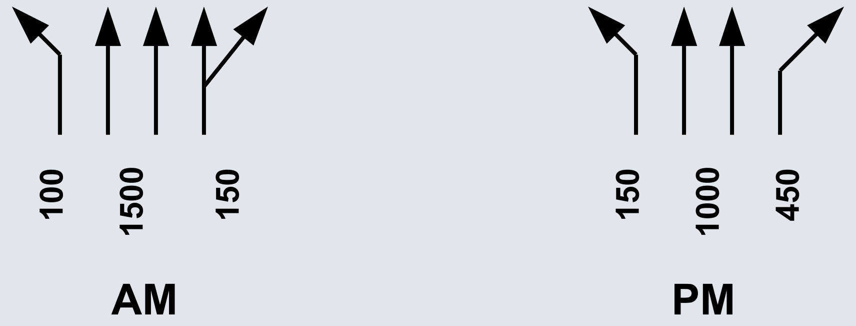
Twice-per-Cycle Left Turns



TIMING WINDOW	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR	PED	HOLD
Lanes and Sharing (#RL)													—	—
Traffic Volume (vph)	0	0	0	71	344	393	440	919	0	0	815	708	—	—
Turn Type	—	—	—	Split	—	Perm	Prot	—	—	—	—	Free	—	—
Protected Phases	—	—	—	8	8		5 13	2	—	—	6			
Permitted Phases	—	—	—			8			—	—		Free	—	—
Detector Phases	—	—	—	8	8	8	5 13	2	—	—	6	None	—	—
Minimum Initial (s)	—	—	—	4.0	4.0	4.0	—	8.0	—	—	8.0	—	—	—
Minimum Split (s)	—	—	—	31.0	31.0	31.0	—	21.0	—	—	19.0	—	—	—
Total Split (s)	—	—	—	32.0	32.0	32.0	41.0	78.0	—	—	37.0	—	—	—
Yellow Time (s)	—	—	—	3.6	3.6	3.6	—	4.0	—	—	4.0	—	—	—
All-Red Time (s)	—	—	—	1.0	1.0	1.0	—	1.0	—	—	1.0	—	—	—
Lead/Lag	—	—	—	—	—	—	—	—	—	—	Lag	—	—	—
Allow Lead/Lag Optimize?	—	—	—	—	—	—	—	—	—	—	Fixed	—	—	—
Recall Mode	—	—	—	None	None	None	—	None	—	—	C-Max	—	—	—
Actuated Effct. Green (s)	—	—	—	—	29.0	29.0	34.5	75.0	—	—	34.5	110.0	—	—
Actuated g/C Ratio	—	—	—	—	0.26	0.26	0.31	0.68	—	—	0.31	1.00	—	—
Volume to Capacity Ratio	—	—	—	—	0.97	0.85	0.89	0.43	—	—	0.94	0.49	—	—
Control Delay (s)	—	—	—	—	74.9	42.4	36.5	8.6	—	—	41.4	1.8	—	—
Queue Delay (s)	—	—	—	—	0.0	1.8	0.0	0.0	—	—	26.7	0.0	—	—
Total Delay (s)	—	—	—	—	74.9	44.2	36.5	8.6	—	—	68.1	1.8	—	—
Level of Service	—	—	—	—	E	D	D	A	—	—	E	A	—	—
Approach Delay (s)	—	0.0	—	—	60.0	—	—	17.6	—	—	37.3	—	—	—
Approach LOS	—	A	—	—	E	—	—	B	—	—	D	—	—	—
Queue Length 50th (ft)	—	—	—	—	331	209	187	206	—	—	260	1	—	—
Queue Length 95th (ft)	—	—	—	—	#546	#393	#301	123	—	—	m#516	m2	—	—

Variable Lane Control

- Variation 1: Modify approach lane configuration by time of day
  - Use EMS sign to designate lane usage
  - Generally no unusual modification to timing required



Variable Lane Control

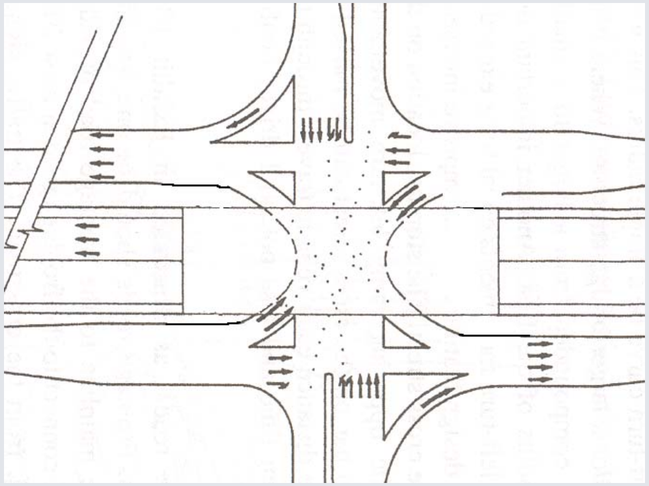
- Variation 2: Alternate direction/use of lane by time of day
  - Use EMS signs to designate lane uses
  - May require special striping to distinguish lane usage
  - Generally requires transition timing plan to clear lane
  - *<u>Example.</u> Lafayette Street in the City of Santa Clara*

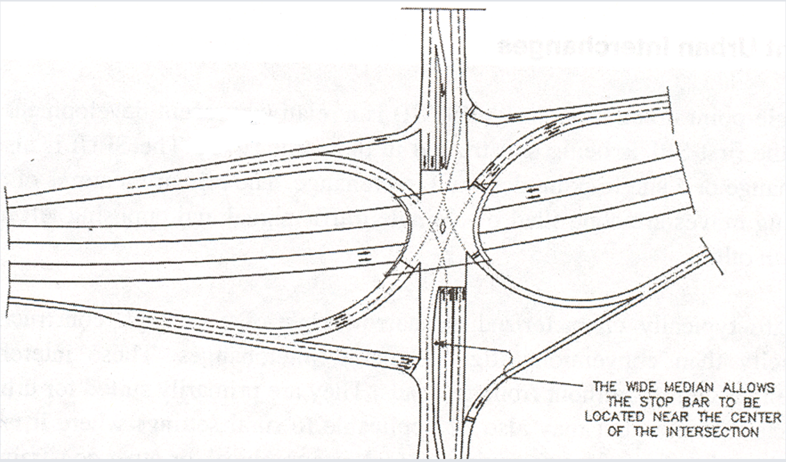
Variable Lane Control

- Variation 3: Time-of-Day HOV or Bus Lane
  - *Example.* *Santa Clara County Expressways*
- Variation 4: Time-of Day Parking Restrictions
  - *Example.* *Martin Luther King Jr. Way in Berkeley*
- Variation 5: Time-of Day Turn Restrictions
  - *Example.* *Ashby Avenue in Berkeley*
  - Use signs to designate restrictions
  - May require special striping to distinguish lane usage
  - Generally no unusual modification to timing required

Single-Point Urban Interchange

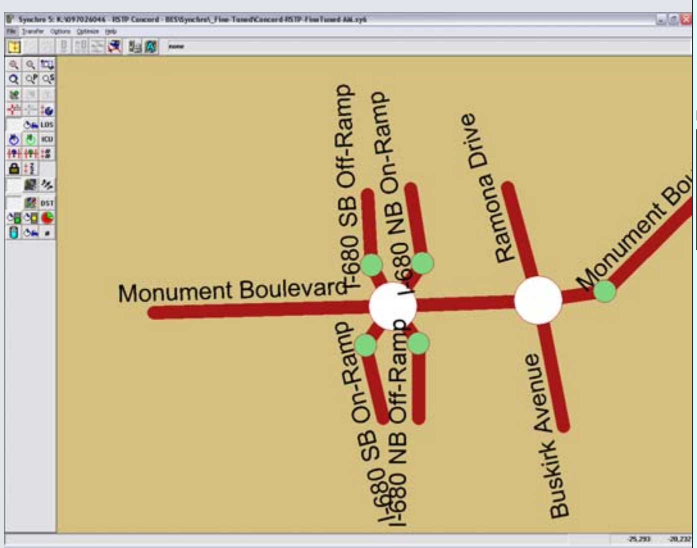
- Compressed Interchange
- Conventional phase control (6- or 8-phase)
- With or without frontage roads
- Right turn signalized or non-signalized
- Greater clearance intervals – 5-10 seconds
- High pedestrian delay
- Model as single standard intersection or 3 intersections with 1 controller

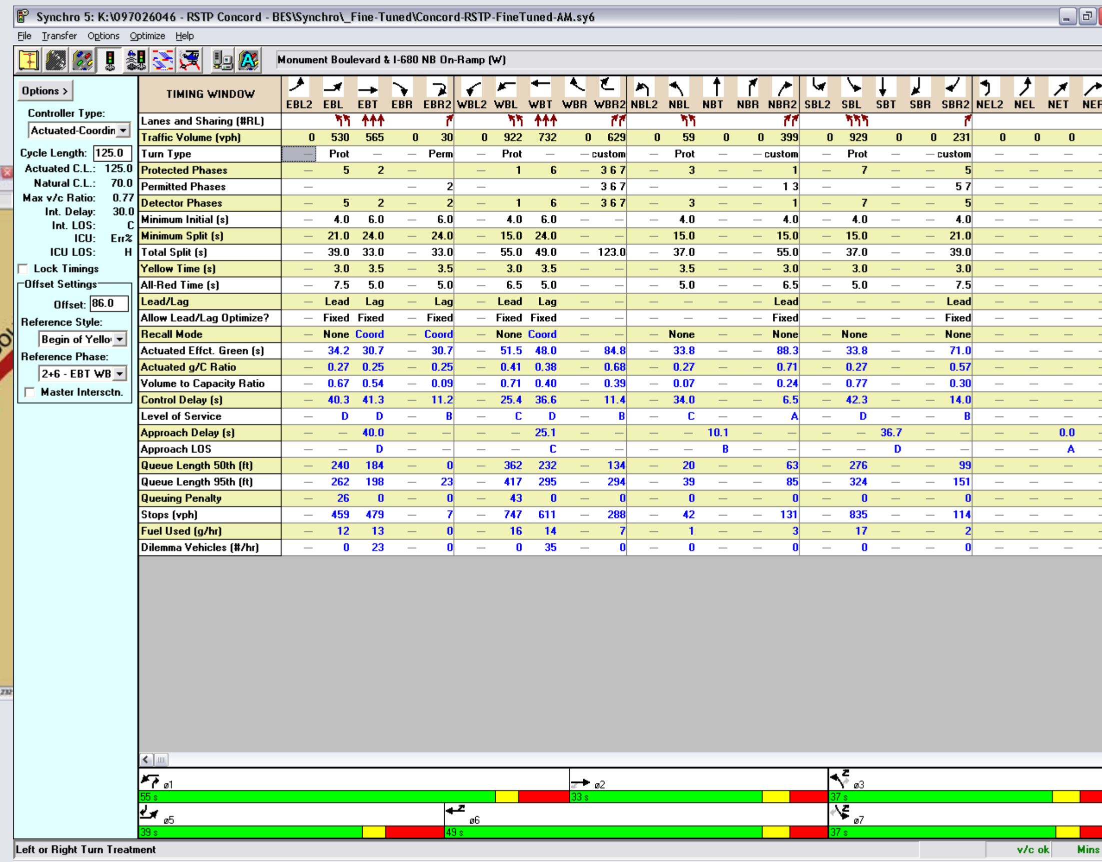




Single-Point Urban Interchange

- Modeled as single standard intersection

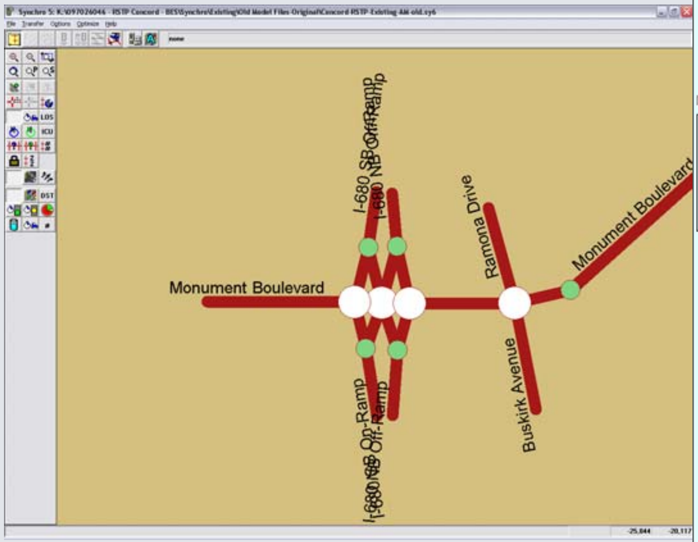


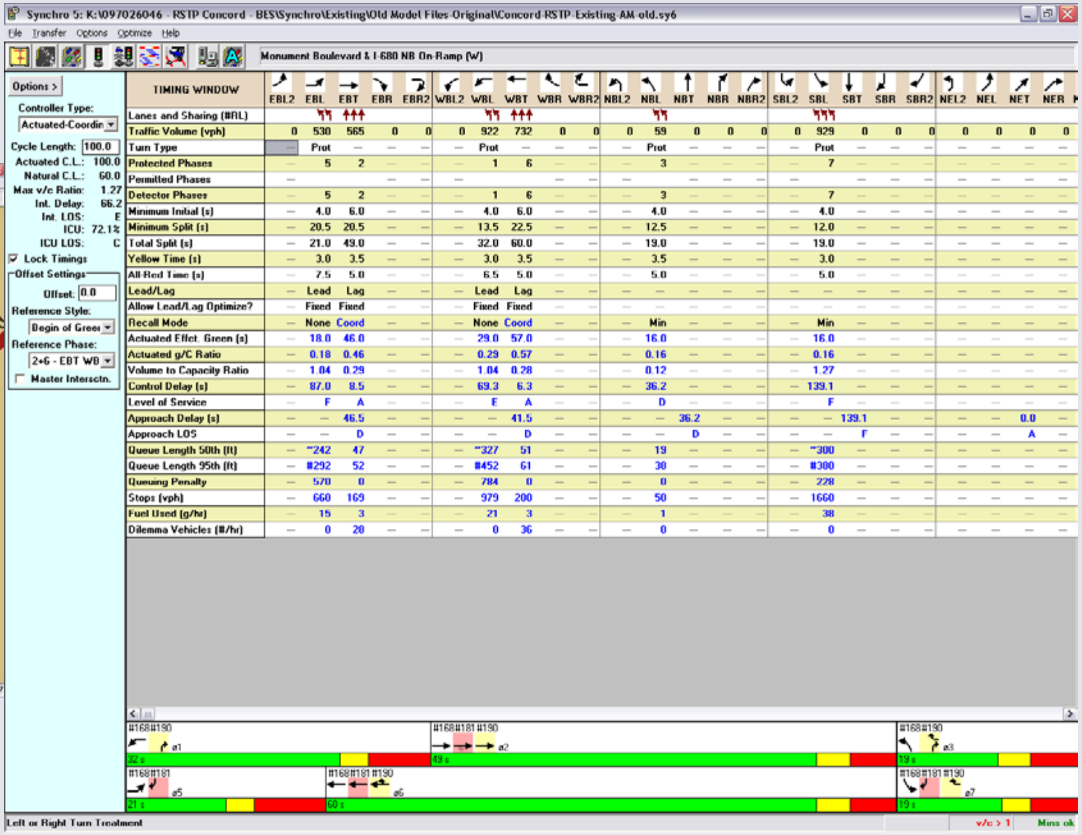


TIMING WINDOW	EBL2	EBL	EBT	EBR	EBR2	WBL2	WBL	WBT	WBR	WBR2	NBL2	NBL	NBT	NBR	NBR2	SBL2	SBL	SBT	SBR	SBR2	NEL2	NEL	NET	NER
Lanes and Sharing (#RL)																								
Traffic Volume (vph)	0	530	565	0	30	0	922	732	0	629	0	59	0	0	399	0	929	0	0	231	0	0	0	0
Turn Type	—	Prot	—	—	Perm	—	Prot	—	—	custom	—	Prot	—	—	custom	—	Prot	—	—	custom	—	—	—	—
Protected Phases	—	5	2	—		—	1	6	—	3 6 7	—	3	—	—	1	—	7	—	—	5	—	—	—	—
Permitted Phases	—			—	2	—			—	3 6 7	—		—	—	1 3	—		—	—	5 7	—	—	—	—
Detector Phases	—	5	2	—	2	—	1	6	—	3 6 7	—	3	—	—	1	—	7	—	—	5	—	—	—	—
Minimum Initial (s)	—	4.0	6.0	—	6.0	—	4.0	6.0	—	—	—	4.0	—	—	4.0	—	4.0	—	—	4.0	—	—	—	—
Minimum Split (s)	—	21.0	24.0	—	24.0	—	15.0	24.0	—	—	—	15.0	—	—	15.0	—	15.0	—	—	21.0	—	—	—	—
Total Split (s)	—	39.0	33.0	—	33.0	—	55.0	49.0	—	123.0	—	37.0	—	—	55.0	—	37.0	—	—	39.0	—	—	—	—
Yellow Time (s)	—	3.0	3.5	—	3.5	—	3.0	3.5	—	—	—	3.5	—	—	3.0	—	3.0	—	—	3.0	—	—	—	—
All-Red Time (s)	—	7.5	5.0	—	5.0	—	6.5	5.0	—	—	—	5.0	—	—	6.5	—	5.0	—	—	7.5	—	—	—	—
Lead/Lag	—	Lead	Lag	—	Lag	—	Lead	Lag	—	—	—	—	—	—	Lead	—	—	—	—	Lead	—	—	—	—
Allow Lead/Lag Optimize?	—	Fixed	Fixed	—	Fixed	—	Fixed	Fixed	—	—	—	—	—	—	Fixed	—	—	—	—	Fixed	—	—	—	—
Recall Mode	—	None	Coord	—	Coord	—	None	Coord	—	—	—	None	—	—	None	—	None	—	—	None	—	—	—	—
Actuated Effct. Green (s)	—	34.2	30.7	—	30.7	—	51.5	48.0	—	84.8	—	33.8	—	—	88.3	—	33.8	—	—	71.0	—	—	—	—
Actuated g/C Ratio	—	0.27	0.25	—	0.25	—	0.41	0.38	—	0.68	—	0.27	—	—	0.71	—	0.27	—	—	0.57	—	—	—	—
Volume to Capacity Ratio	—	0.67	0.54	—	0.09	—	0.71	0.40	—	0.39	—	0.07	—	—	0.24	—	0.77	—	—	0.30	—	—	—	—
Control Delay (s)	—	40.3	41.3	—	11.2	—	25.4	36.6	—	11.4	—	34.0	—	—	6.5	—	42.3	—	—	14.0	—	—	—	—
Level of Service	—	D	D	—	B	—	C	D	—	B	—	C	—	—	A	—	D	—	—	B	—	—	—	—
Approach Delay (s)	—	—	40.0	—	—	—	—	25.1	—	—	—	—	10.1	—	—	—	—	36.7	—	—	—	—	0.0	—
Approach LOS	—	—	D	—	—	—	—	C	—	—	—	—	B	—	—	—	—	D	—	—	—	—	A	—
Queue Length 50th (ft)	—	240	184	—	0	—	362	232	—	134	—	20	—	—	63	—	276	—	—	99	—	—	—	—
Queue Length 95th (ft)	—	262	198	—	23	—	417	295	—	294	—	39	—	—	85	—	324	—	—	151	—	—	—	—
Queuing Penalty	—	26	0	—	0	—	43	0	—	0	—	0	—	—	0	—	0	—	—	0	—	—	—	—
Stops (vph)	—	459	479	—	7	—	747	611	—	288	—	42	—	—	131	—	835	—	—	114	—	—	—	—
Fuel Used (g/hr)	—	12	13	—	0	—	16	14	—	7	—	1	—	—	3	—	17	—	—	2	—	—	—	—
Dilemma Vehicles (#/hr)	—	0	23	—	0	—	0	35	—	0	—	0	—	—	0	—	0	—	—	0	—	—	—	—

Single-Point Urban Interchange

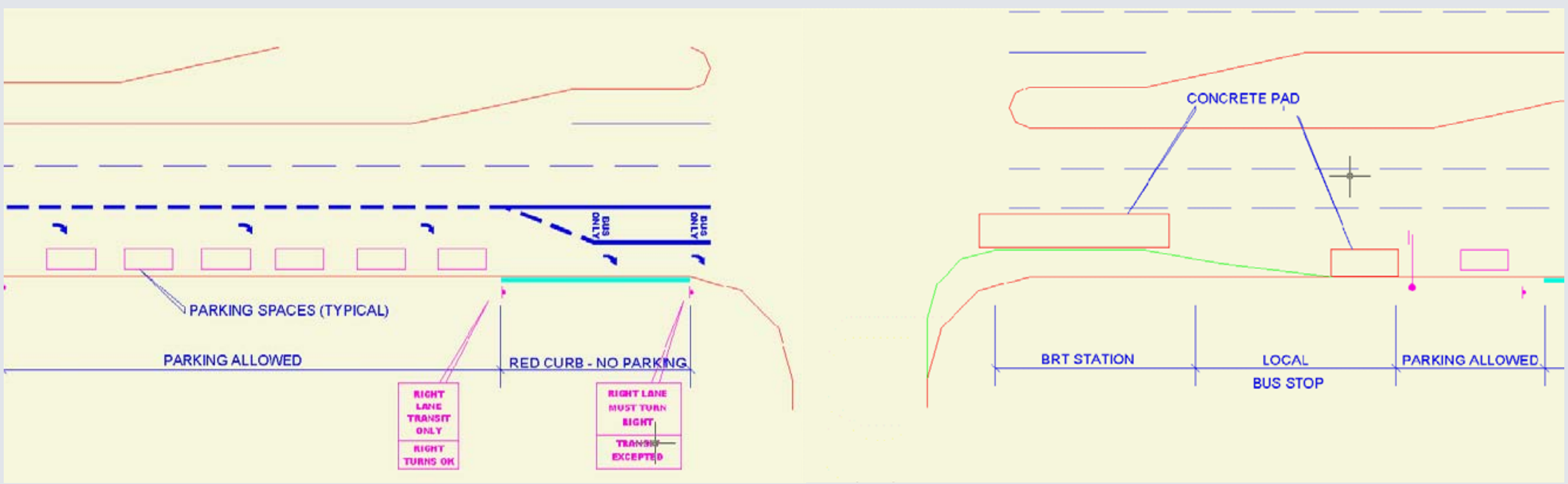
- Modeled as three intersections with one controller





Bus Queue Jumping

- Provides exclusive advanced green to transit vehicles to bypass the queue
- Uses additional phase(s) outside the standard 8-phases
- No impact on coordination since the transit phase is programmed in the cycle as a typical phase
- *__Example.__ First and Howard in San Francisco*

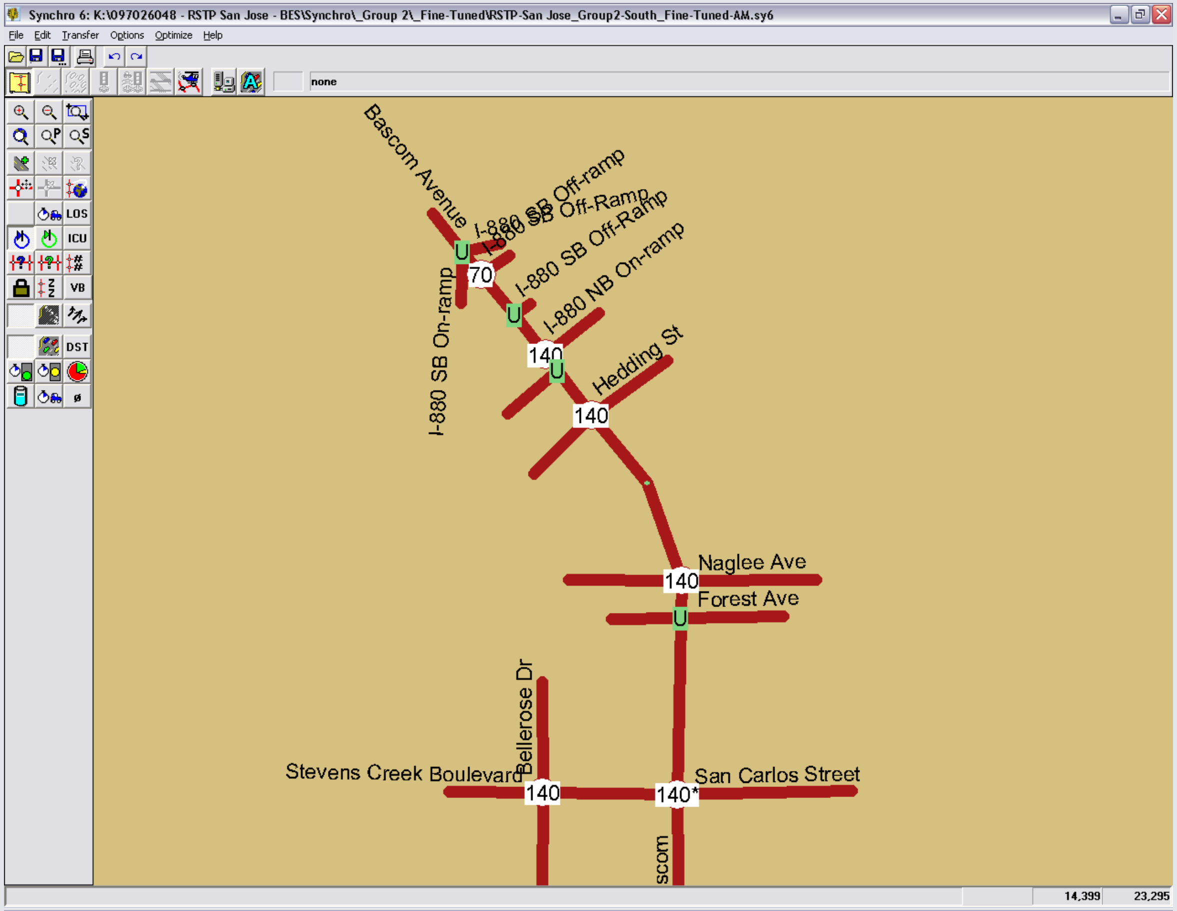


Balancing Corridor Needs at Interchanges

- Problem:
  - Interchange signals often require lower cycle lengths (under 100 sec) than arterial signals because of less storage and heavy ramp and turn volumes
- Strategies:
  - Limited Ramp Storage – half-cycle interchange intersections or coordinate with closest adjacent signals only
  - Heavy Ramp Volume – progress ramp traffic rather than arterial through traffic
  - Long Ramp Storage and Heavy Through Traffic on Arterial – ok to use higher cycle lengths
  - *Examples. Brokaw @ I-880 and Tully @ US-101 in San Jose*

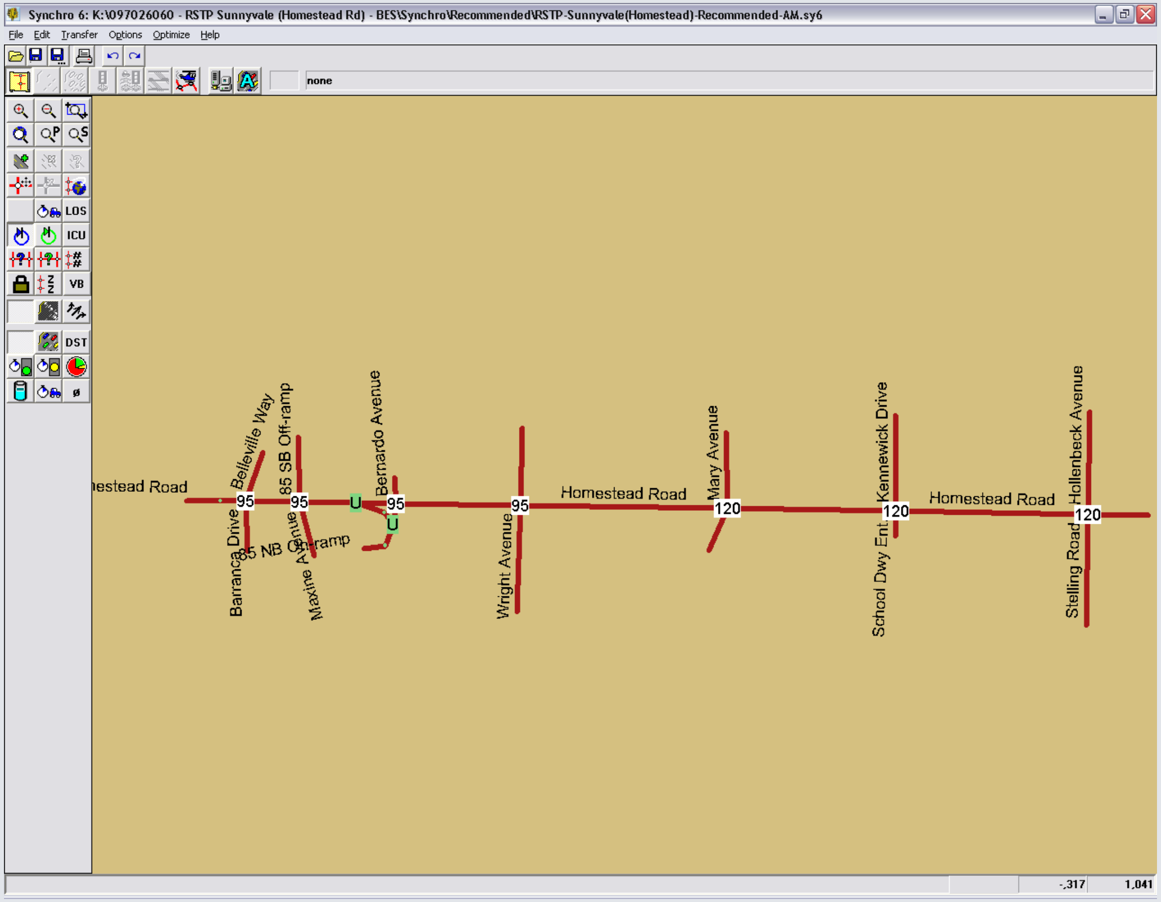
Balancing Corridor Needs at Interchanges

- Half-Cycle Length Example



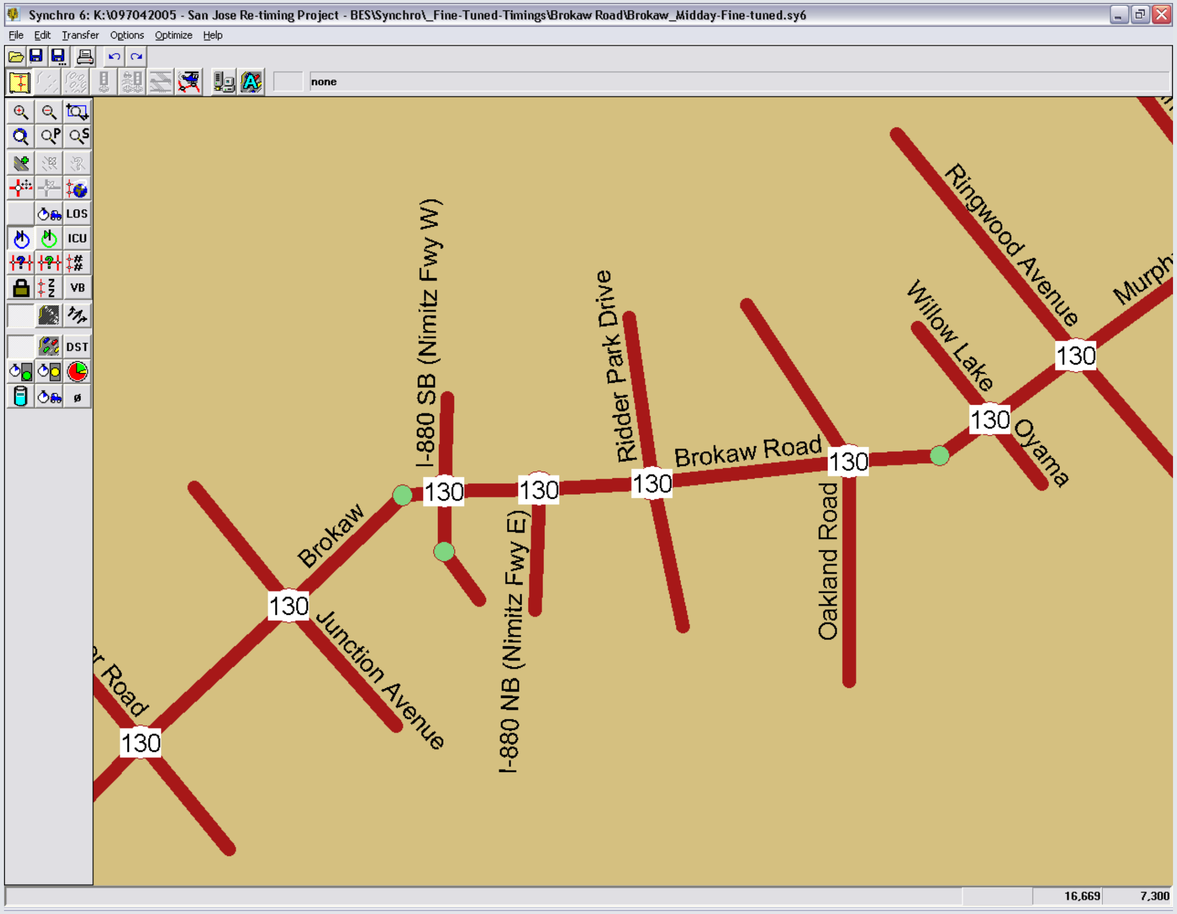
Balancing Corridor Needs at Interchanges

- Split Signal Groups Example



Balancing Corridor Needs at Interchanges

- Common, Higher Cycle Length Example



Balancing Corridor Needs for Expressways

- Expressways require very high cycle lengths (140-190 seconds)
- Few crossing arterials that require or should operate with as high cycle lengths
- Rarely feasible to half-cycle crossing arterial signals
- Balance crossing roadway needs by providing sufficient side street split time

Ramp Metering Operations

- Ramp metering rates and mainline operations
- Excessive queuing on the ramp
- Queue spillbacks into intersections
- Diversion strategies – using ITS to inform motorists of delays at on-ramps
- Intersection operations strategies
  - Holding phases that cannot be received on the ramp
  - Restricting turns during peak hours
  - If queue storage on the arterial is available, ignore ramp volume in cycle analysis

V. Timing for Pedestrians and Bicyclists

- Goal:
  - Provide sufficient time for pedestrians and bicyclists to safely cross signalized intersections
- Strategies and Considerations for Pedestrians
- Strategies and Considerations for Bicyclists

Pedestrian Timing Strategies

- Leading Pedestrian Intervals
  - Provides pedestrians with a few seconds of lead time prior to onset of associated vehicle phase
  - Makes pedestrians more visible
- Pedestrian Delay
  - Vehicle phase starts prior to the onset of the associated pedestrian phase

Pedestrian Timing Strategies

- Exclusive Pedestrian Interval or Pedestrian Scramble
  - Provides an all-red indication to all vehicular traffic while pedestrians cross
  - Ideal for high pedestrian-volume intersections
  - Need to restrict RTOR during ped phase
  - May allow pedestrians to cross diagonally through signs and markings
  - Increases cycle length
  - May need educational campaign and additional enforcement in beginning
  - *Example. 8th and Webster in Oakland*

Pedestrian Timing Strategies

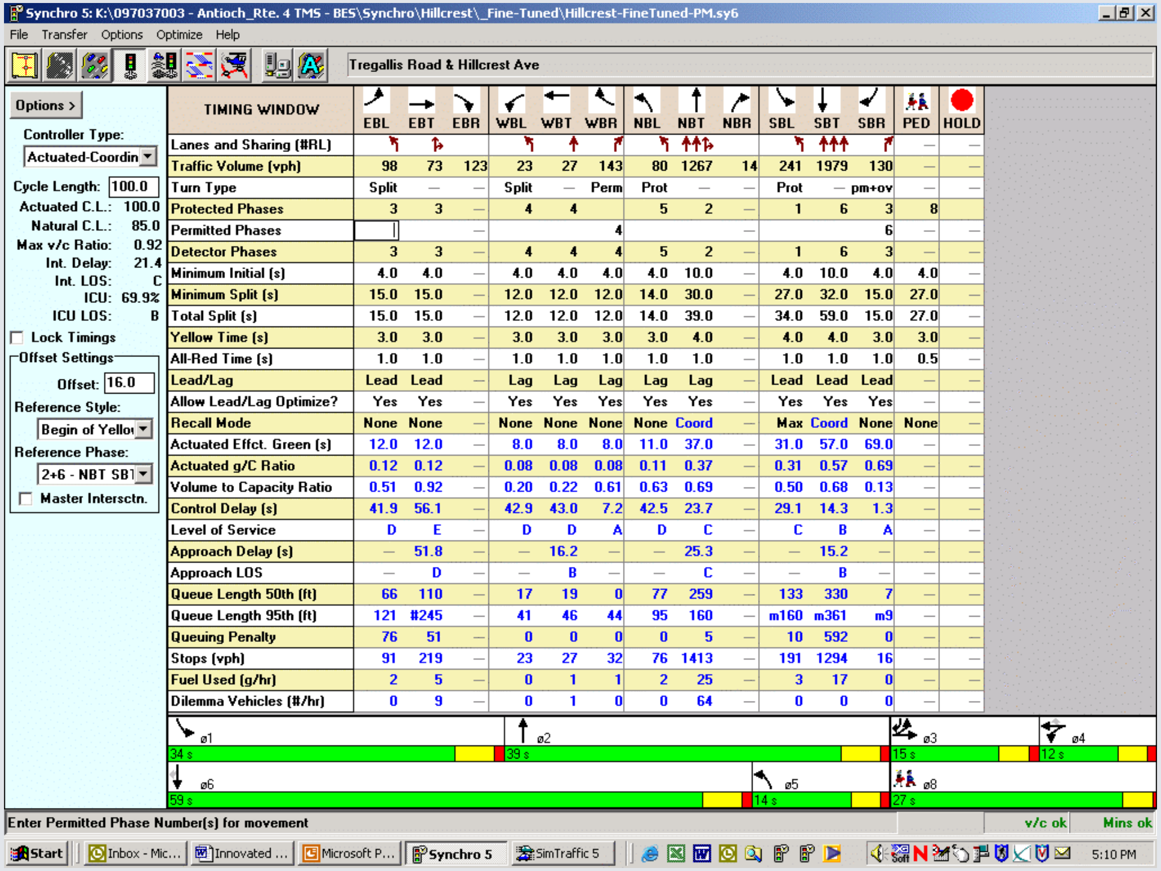
- Extended FDW time
  - Provides option to activate longer pedestrian clearance time by holding PPB longer
  - Ideal for intersections with lots of young, elderly, or disabled pedestrians
- FDW through yellow
  - The FDW clearance is timed through the yellow clearance interval rather than prior to the yellow interval (typical)

Pedestrian Timing Strategies

- Pedestrian recycle options
  - Allows for re-service of a pedestrian phase during a single cycle if there is sufficient time
  - Certain controllers have multiple conditions for allowing or not allowing pedestrian recycling
- Extended Walk
  - During coordination the Walk for the coordinated phase can be extended to the latest point in the split that will still allow the full pedestrian clearance interval

Pedestrian Timing

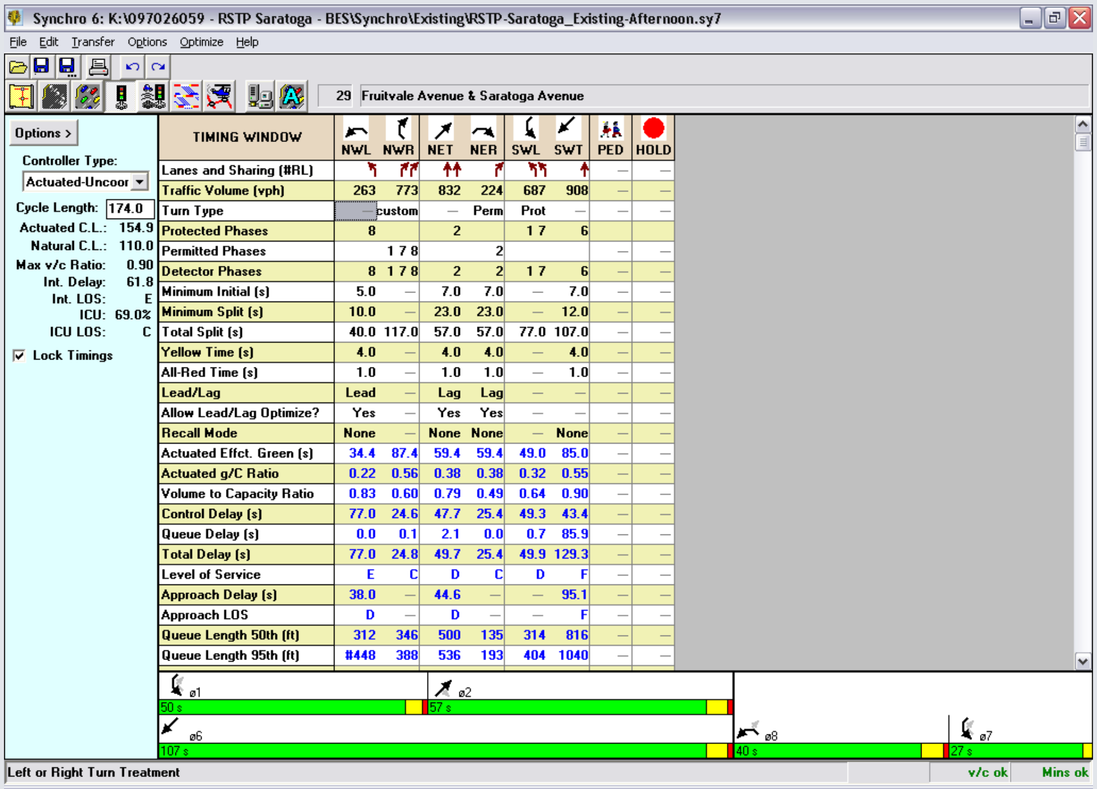
- Overlap
  - Split phase



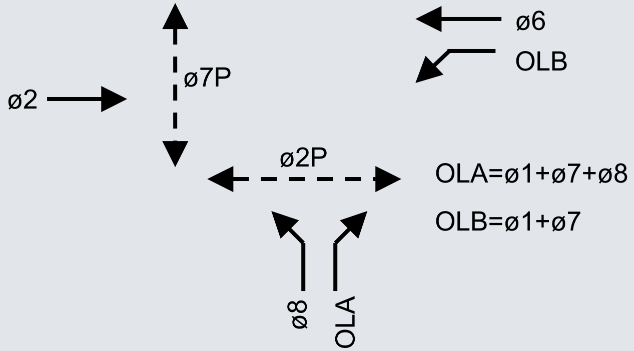
TIMING WINDOW	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR	PED	HOLD
Lanes and Sharing (#RL)													—	—
Traffic Volume (vph)	98	73	123	23	27	143	80	1267	14	241	1979	130	—	—
Turn Type	Split	—	—	Split	—	Perm	Prot	—	—	Prot	—	pm+ov	—	—
Protected Phases	3	3	—	4	4		5	2	—	1	6	3	8	
Permitted Phases			—			4			—			6	—	—
Detector Phases	3	3	—	4	4	4	5	2	—	1	6	3	—	—
Minimum Initial (s)	4.0	4.0	—	4.0	4.0	4.0	4.0	10.0	—	4.0	10.0	4.0	4.0	—
Minimum Split (s)	15.0	15.0	—	12.0	12.0	12.0	14.0	30.0	—	27.0	32.0	15.0	27.0	—
Total Split (s)	15.0	15.0	—	12.0	12.0	12.0	14.0	39.0	—	34.0	59.0	15.0	27.0	—
Yellow Time (s)	3.0	3.0	—	3.0	3.0	3.0	3.0	4.0	—	4.0	4.0	3.0	3.0	—
All-Red Time (s)	1.0	1.0	—	1.0	1.0	1.0	1.0	1.0	—	1.0	1.0	1.0	0.5	—
Lead/Lag	Lead	Lead	—	Lag	Lag	Lag	Lag	Lag	—	Lead	Lead	Lead	—	—
Allow Lead/Lag Optimize?	Yes	Yes	—	Yes	Yes	Yes	Yes	Yes	—	Yes	Yes	Yes	—	—
Recall Mode	None	None	—	None	None	None	None	Coord	—	Max	Coord	None	None	—
Actuated Effct. Green (s)	12.0	12.0	—	8.0	8.0	8.0	11.0	37.0	—	31.0	57.0	69.0	—	—
Actuated g/C Ratio	0.12	0.12	—	0.08	0.08	0.08	0.11	0.37	—	0.31	0.57	0.69	—	—
Volume to Capacity Ratio	0.51	0.92	—	0.20	0.22	0.61	0.63	0.69	—	0.50	0.68	0.13	—	—
Control Delay (s)	41.9	56.1	—	42.9	43.0	7.2	42.5	23.7	—	29.1	14.3	1.3	—	—
Level of Service	D	E	—	D	D	A	D	C	—	C	B	A	—	—
Approach Delay (s)	—	51.8	—	—	16.2	—	—	25.3	—	—	15.2	—	—	—
Approach LOS	—	D	—	—	B	—	—	C	—	—	B	—	—	—
Queue Length 50th (ft)	66	110	—	17	19	0	77	259	—	133	330	7	—	—
Queue Length 95th (ft)	121	#245	—	41	46	44	95	160	—	m160	m361	m9	—	—
Queuing Penalty	76	51	—	0	0	0	0	5	—	10	592	0	—	—
Stops (vph)	91	219	—	23	27	32	76	1413	—	191	1294	16	—	—
Fuel Used (g/hr)	2	5	—	0	1	1	2	25	—	3	17	0	—	—
Dilemma Vehicles (#/hr)	0	9	—	0	1	0	0	64	—	0	0	0	—	—

Pedestrian Timing

- Overlap
  - Left Turn



TIMING WINDOW	NWL	NWR	NET	NER	SWL	SWT	PED	HOLD
Lanes and Sharing (#RL)							—	—
Traffic Volume (vph)	263	773	832	224	687	908	—	—
Turn Type	—	custom	—	Perm	Prot	—	—	—
Protected Phases	8		2		1 7	6		
Permitted Phases		1 7 8		2			—	—
Detector Phases	8	1 7 8	2	2	1 7	6	—	—
Minimum Initial (s)	5.0	—	7.0	7.0	—	7.0	—	—
Minimum Split (s)	10.0	—	23.0	23.0	—	12.0	—	—
Total Split (s)	40.0	117.0	57.0	57.0	77.0	107.0	—	—
Yellow Time (s)	4.0	—	4.0	4.0	—	4.0	—	—
All-Red Time (s)	1.0	—	1.0	1.0	—	1.0	—	—
Lead/Lag	Lead	—	Lag	Lag	—	—	—	—
Allow Lead/Lag Optimize?	Yes	—	Yes	Yes	—	—	—	—
Recall Mode	None	—	None	None	—	None	—	—
Actuated Effct. Green (s)	34.4	87.4	59.4	59.4	49.0	85.0	—	—
Actuated g/C Ratio	0.22	0.56	0.38	0.38	0.32	0.55	—	—
Volume to Capacity Ratio	0.83	0.60	0.79	0.49	0.64	0.90	—	—
Control Delay (s)	77.0	24.6	47.7	25.4	49.3	43.4	—	—
Queue Delay (s)	0.0	0.1	2.1	0.0	0.7	85.9	—	—
Total Delay (s)	77.0	24.8	49.7	25.4	49.9	129.3	—	—
Level of Service	E	C	D	C	D	F	—	—
Approach Delay (s)	38.0	—	44.6	—	—	95.1	—	—
Approach LOS	D	—	D	—	—	F	—	—
Queue Length 50th (ft)	312	346	500	135	314	816	—	—
Queue Length 95th (ft)	#448	388	536	193	404	1040	—	—



Pedestrian Timing Considerations

- MUTCD FDW Requirements
  - MUTCD (2003) Section 4E.10 Standard states “The pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder during the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 1.2m (4 ft) per second, to at least the far side of the traveled way or to median of sufficient width for pedestrians to wait”.
  - Previous MUTCD stated “…to the middle of the farthest travel lane..”
  - New MUTCD increases ped clearance time typically by 2-3 seconds

Pedestrian Timing Considerations

- MUTCD FDW Requirements
  - Distance considerations – What is “end of traveled way”
    - Where in crosswalk measured?
    - Exclude parking lane
    - Include bike lane?
    - Curb line extended
  - Other considerations
    - Slower pedestrian speeds
    - Alternative measurements (ramp to ramp)
    - Include yellow time in FDW time? (MUTCD allows for yellow time to be part of FDW time)
  - Higher clearance time generally results in need for higher cycle lengths in coordination and higher vehicular delay

Pedestrian Timing Considerations

- Ways to enhance pedestrian safety at signalized intersections without affecting timing:
  - Pedestrian countdown signals
  - Accessible pedestrian signals
  - Scanning eyes
  - Advanced limit lines and other markings

Bicycle Timing Considerations

- Bicycles require longer crossing time
- Program dedicated minimum green time
  - Either through separate phase bank or through controller feature
  - *Example. Santa Clara County Expressways*
- Extended all-red clearance from bike detection

Questions?